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AN OPTIMIZATION OF MACHINE AND OPERATIONAL PARAMETERS ON SEED PLACEMENT INDEX FOR PRECISION SOWING OF BLACK GRAM

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ABSTRACT

For achieving desired seed placement index for black gram variety VBN-3, a laboratory test rig was developed with the following independent variables. Cell geometry (S) - 3 levels -Maximum seed dimension - 4.25 mm, 10 per cent more than maximum seed dimension - 4.67 mm and 25 per cent more than maximum seed dimension - 5.31 mm. Inclination of seed metering disc (θ) - 4 levels - 30°, 35°, 40° and 45°. Peripheral speed of seed metering disc (V) - 4 levels - 0.1 ms-1, 0.15 ms-1, 0.2 ms-1 and 0.25 ms-1. From the experiments, it was inferred that the cell geometry with 10 percent maximum seed dimension registered maximum seed placement index. The angle of inclination of the seed metering disc had no profound effect on SPI for all levels of combination. At 0.20 ms-1 peripheral velocity of seed metering disc, the cell geometry 4.67 mm (10 per cent more than the maximum seed dimension) yielded higher SPI than the cell geometry of 4.25 mm and 5.31 mm.

***KEYWORDS:** Black Gram, Seed Geometry, Peripheral Velocity & Seed Placement Index*

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Original Article

1. INTRODUCTION

For maintaining accurate seed rate and seed spacing during metering, it is very much necessary to drop the desired number of seeds in rows at optimum depth. Among different sowing techniques, precision sowing is the preferred method at present, since it maintains a more uniform seed spacing and optimum plant population than other methods. Precision planting saves seeds and utilize fertilizer to the best advantage and increases yield by enabling good cultivation practices. Precision planting technique results in uniform plant spacing, depth and aids further mechanization of intercultural farming operation that will reduce the total production cost. Shrivastava et al. (2003) evaluated the performance of tractor drawn six rows inclined plate planter for oil seeds and pulses. They reported that the use of planting equipment with inclined plate seed metering device for the precision planting of peanuts has found to increase the efficiency use of seeds and reduce the cost of production.

Jayan and Kumar (2004) investigated the design of planter in relation to the physical properties of seeds. They reported that in absence of devices for the positive removal of seeds from the cells of the plate, seeds dropped by gravity and as the peanut seeds are non-spherical, they move slowly leading to the variation in seed spacing. In order to achieve the uniformity in seed spacing and accuracy in seed rate, it is essential to use the metering plate with size of cells matching to the size of seeds. Aware et al. (2004) developed an inclined plate metering mechanism for planting of peanuts. It consists of a hopper, cell plate, ground wheel, electronic circuit,

and the mounting frame. The designed electronic metering mechanism was tested with a forward speed of 1 km h^{-1} in the laboratory by using the grease board. They reported the average hill to hill spacing of 13.3 cm was obtained from laboratory test, which was close to hill to hill spacing value compared to the recommended plant to plant spacing of 13 cm. Anantachar et al. (2010) reported that seed planting equipment with inclined plate seed metering devices is the most commonly used equipment for planting of the peanut crop in India. For obtaining the high yield, it is very essential to drop the peanut seeds in rows, maintaining accurate seed rate and seed spacing with minimum damage to seeds during metering. This mainly depends on the forward speed of the planting equipment, rotary speed of the metering plate and area of cells on the plate. Sahoo and Srivastava (2008) investigated the seed pattern characteristics of soaked okra seed with different metering systems viz., vertical roller, horizontal plate, horizontal plate (edge drop), inclined plate, cell size viz., (maximum seed dimension,10% more than maximum seed dimension, 25% more than maximum seed dimension and cell speed viz., 10,14,18, 24 rpm. They concluded that the average spacing was close to theoretical spacing for vertical roller, horizontal plate, horizontal plate (edge drop) with cell size 10% more than the maximum seed dimensions. But in case of inclined plate the average spacing was close to theoretical spacing with the cell size equal to maximum seed dimensions. The quality of feed index was influenced highly by the metering systems, cell size and cell speed. The quality of feed index decreased with increase in speed. However, with an increase in cell speed to 14 rpm only a 5% decrease of quality of feed index was observed. The cell speed influenced the multiple index, miss index and degree of variation the most. The metering system influenced the seed damage the most followed by cell speed. The incline plate metering system was found the best for planting soaked okra seed. In India, a large number of planters are available for sowing cotton, maize, soybean, groundnut and pea (Sahoo and Srivastava, 2000). On the other hand, very limited research work was done on the mechanical sowing of black gram seed. Keeping the above facts in view, the present work on optimizing the cell geometry of the inclined plate planter for black gram seed was investigated to develop a prototype of the planter.

2. MATERIALS AND METHODS

The physico-engineering properties that affect the planter design viz., seed geometry, angle of repose, bulk density and 1000 seed weight were determined by standard methods. The predominant variety VBN-3 adopted by Tamil Nadu farmers was used for the study. The major and minor axis of randomly selected 100 black gram seeds were measured by using vernier caliper. For achieving desired seed placement index a laboratory test rig was developed with the following independent variables. Cell geometry (S) - 3 levels -Maximum seed dimension - 4.25 mm, 10 per cent more than maximum seed dimension - 4.67 mm and 25 per cent more than maximum seed dimension - 5.31 mm. Inclination of seed metering disc (θ) - 4 levels - 30°, 35°, 40° and 45°. Peripheral speed of seed metering disc (V) - 4 levels - 0.1 ms^{-1}, 0.15 ms^{-1}, 0.2 ms^{-1} and 0.25 ms^{-1}.

2.1 Seed Metering Disc

Twelve numbers of seed metering disc were fabricated using 50 mm thickness and 120 mm diameter fiber sheet. The numbers of cells in the seed metering disc vary corresponding to the selected levels of peripheral speed and cell geometry. The number of cells in the seed metering disc was arrived as detailed below.

Recommended spacing between hills for black gram, m - 0.1

Ground wheel diameter of the prototype pulse seed, m (Assumed) - 0.36

Diameter of seed metering disc, m - 0.12

The forward speed of the tractor (selected), km h^{-1} - 1.5

Rotational speed of seed metering disc corresponding to 0.1 ms^{-1} peripheral velocity (V_1)

$$= \frac{\text{Peripheral velocity, } ms^{-1} \times 60}{\pi \times \text{Diameter of seed metering disc, } m}$$

= 0.1 x 60 / π x 0.12

= 15.91 rpm

Rotational speed of ground wheel

$$= \frac{\text{Forward speed operation, } Kmh^{-1}}{60 \times \pi \times \text{Ground wheel diameter}}$$

=1.5 x1000/60 x π x0.36

= 22.10 rpm

Speed ratio between ground wheel and seed metering disc

$$= \frac{\text{Speed of seed metering disc}}{\text{Speed of ground wheel}}$$

= 15.91/22.10

=0.72

Revolution of ground wheel to drop one seed

$$= \frac{\textit{Recommended spacing between hills, } m}{\pi \times \textit{Diameter of ground wheel, } m}$$

$$= \frac{0.10}{\pi \times 0.36}$$

= 0.088

Revolution of seed metering disc to drop one seed

=Rev. of G. wheel to drop one seed x Ratio of G. wheel to seed metering disc

= 0.088 x 0.72

= 0.063

No of cells on the seed metering disc

= 1/ Speed of seed metering disc to drop one seed

= 1/0.063

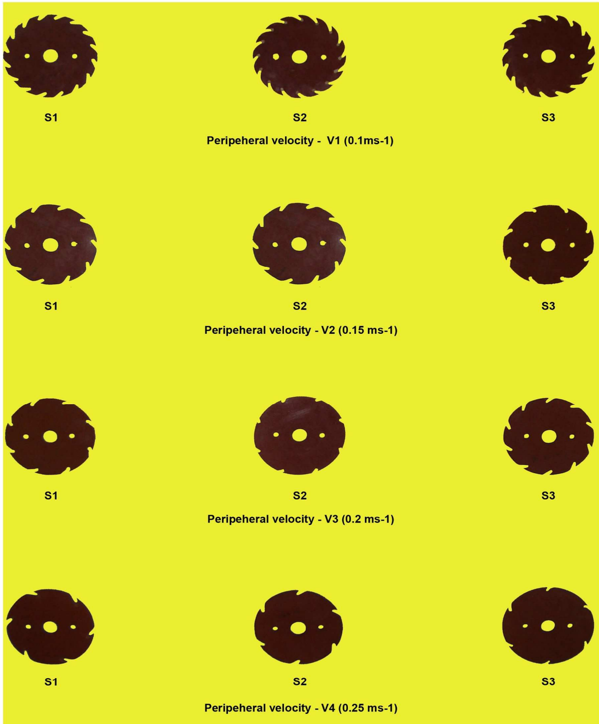
= 15.70 ≈ 16

Spacing between cells on seed plate, cm

$$= \frac{\pi \times \textit{Seed metering disc diameter, m} \times 100}{\text{No of cells on the seed metering disc}}$$

=2.35 cm

Similarly for the other three selected levels of peripheral velocity of 0.15 (V_2), 0.20 (V_3) and 0.25 (V_4) ms^{-1}, the required number of cells of the seed metering disc was arrived as 10, 8 and 6 cells respectively. For selected four levels of peripheral velocities, three discs of each maximum seed dimension (S_1), 10 percent more than maximum seed dimension (S_2) and 25 percent more than maximum seed dimension (S_3) were fabricated and the seed metering discs are shown in plate 1.



S1 - Maximum seed dimension (4.25 mm)

S2 - 10 Per cent more than maximum seed dimension (4.67 mm)

S3 - 25 Per cent more than maximum seed dimension (5.31 mm)

Plate 1: Seed Metering Disc

For operating the inclined plate seed metering disc at selected levels of peripheral speed, the rotational speed of the seed metering drive shaft was calculated as furnished below.

Recommended spacing between hills for pulse crop, m	- 0.1
Diameter of ground wheel diameter, m	- 0.36
Diameter of seed metering disc, m	- 0.12
Forward speed of the tractor, km h^{-1}(Constant)	- 1.5

Rotational speed of seed metering disc

$$= \frac{\text{Peripheral velocity, } ms^{-1} \times 60}{\pi \times \text{Diameter of seed metering disc, } m}$$

For the selected level of peripheral speed of 0.1 ms-1, the rotational speed of seed metering disc

= (0.1 x 60) / (π x 0.12) = 15.91 ≈ 16

Similarly for the other three selected levels of peripheral velocities of 0.15, 0.20, and 0.25 ms^{-1}, the required number of revolutions of seed metering discs per min was arrived as 24, 32 and 40 rpm respectively.

2.2 Laboratory Investigation using Test Rig

An experimental test rig was employed to investigate the effect of chosen levels of independent variables on seed spacing, seed rate and the seed placement index (Panning et al., 2000). An experimental test rig was developed in the department of the farm machinery workshop, Tamil Nadu Agricultural University, Coimbatore. The test rig consists of a frame, a pair of DC motor with worm gear box (one for the seed metering disc operation and other for the operation of conveyor belt), similarly a pair of controller was employed for the supply of power for the seed metering disc and for the conveyor belt.

The quantity of seeds in the metering section was maintained at a constant level up to the level of the sleeve with the help of sliding gate. A 75 mm diameter pulley was fitted at the other end of the seed metering drive shaft. The entire seed metering unit was mounted on the top of the main frame. A 75 mm diameter pulley fitted with one of the DC motor was connected to the pulley of the seed metering unit by “V” belt drive. For obtaining the selected levels of inclination of the seed metering disc viz., 30°, 35°, 40° and 45°, four wooden blocks with leveled base and inclined corresponding to the inclination of the disc were used in between the main frame and the seed metering unit. The operational view of the test rig is shown in plate 2.

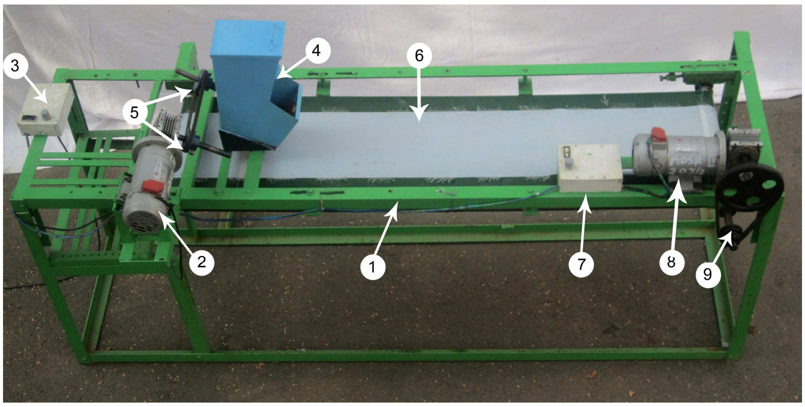


Plate 2. Operational view of test rig

1.Main frame 2.DC motor for seed metering unit 3.Controller for DC motor (I) 4.Seed metering unit 5.Power transmission for seed metering unit 6. Grease coated conveyor belt 7. Controller for DC motor (II) 8. DC motor for conveyor belt 9. Power transmission for conveyor belt

2.3 Evaluational Parameters

In crop production, the main condition for high productivity depends on seeds being in the optimum living area. In other words, it is necessary for seeds to be placed at equal intervals within rows. With uniform spacing, the roots can grow to a uniform size (Steffen et al., 1999; Panning et al., 2000). Seed drill performance factors include accuracy of drop points, multiples and misses as well as seed bounces and rolls (Lan et al., 1999). The efficiency of planting unit usually expressed in terms of seed rate (kg ha^{-1}), spacing between hills (mm), percentage of hills with one or two seeds, percentage of hills with more than two seeds, percentage of missing hills, seed placement index (SPI) and visible seed damage as reported by earlier scientists (Karayel and Ozmerzi, 2002; Pradeeprajan and Sirohi, 2004; Staggenborg et al., 2004; Karayel et al., 2005 and Singh et al. 2005).

The total number of hills, number of hills with one seed, number of hills with two seed number of hills with more than two seeds and number of hills with no seed over a 3.87 m distance of the grease coated conveyor belt was measured. The same procedure was repeated thrice for all the treatments of the investigation. From the measured values of percentage of hills with two seeds, percentage of hills with one seed, percentage of hills with more than two seeds and percentage of missing hills, the seed placement index (SPI) was calculated by using the following expression.

$$SPI = \frac{\%\text{ of hills having (one seed+two seed)}}{\%\text{ Of hills having (one seed+two seed+no seed+ > two seeds)}} \times 100$$

3. RESULTS AND DISCUSSIONS

A total number of 144 experiments were conducted using the experimental test rig with selected levels of variables. The number of hills with one, two, more than two seeds and zero seeds were recorded for all the treatments of the investigation. The effects of selected levels of variables on the seed placement index are analysed and presented below.

3.1. Effect of Peripheral Velocity of Seed Metering Disc (V) on SPI

The effect of peripheral velocity of the seed metering disc (V) on SPI at selected levels of inclination of seed metering disc (θ) and cell geometry (S) is shown in Figure 1

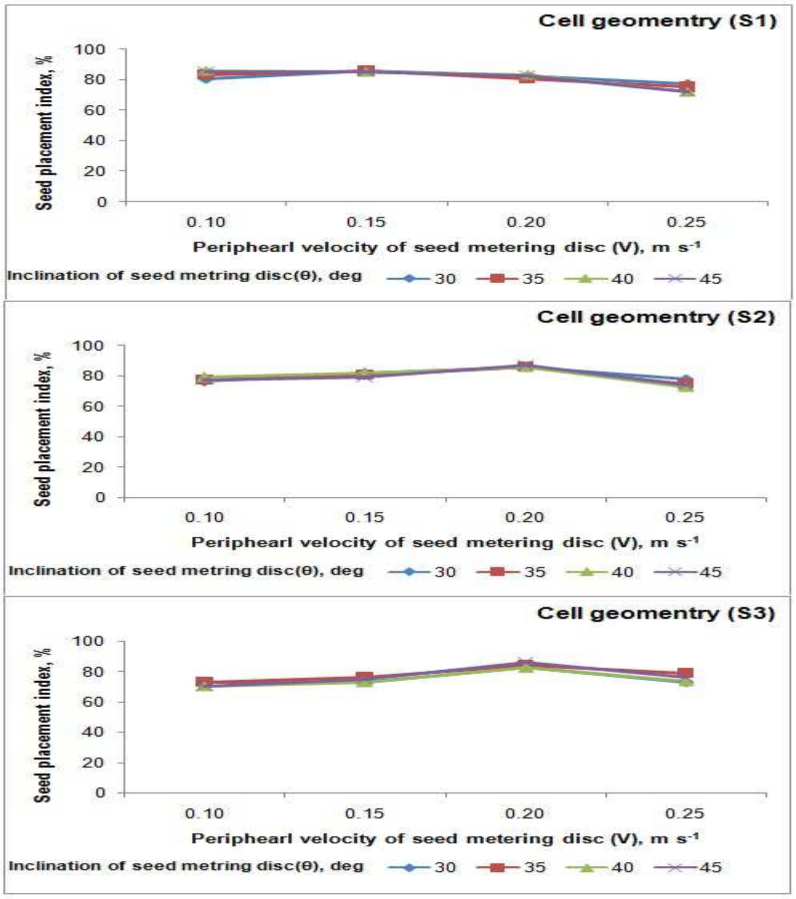


Figure 1: The Effect of Peripheral Velocity of Seed Metering Disc (v) on SPI at Selected Levels of Inclination of Seed Metering Disc (θ) and Cell Geometry(S)

3.1.1. Maximum Seed Dimension (S_1)

It is observed that an increase in peripheral velocity of the seed metering disc from 0.10 (V_1) to 0.20 ms^{-1} (V_3) resulted in marginal variation in SPI irrespective of inclination of the seed metering disc. Further increase in peripheral velocity up to 0.25 ms^{-1} (V_4) resulted in 6.4, 7.1, 13.7 and 12.8 per cent reduction of SPI at 30° (θ_1), 35° (θ_2), 40° (θ_3) and 45° (θ_4) inclination of seed metering disc respectively.

3.1.2. 10 per cent more than Maximum Seed Dimension (S_2)

The increase in SPI was 12.6, 11.4, 8.9 and 8.0 per cent with an increase in peripheral velocity of the seed metering disc from 0.10 (V_1) to 0.20 ms^{-1} (V_3) at selected levels of inclination of 30° (θ_1), 35° (θ_2), 40° (θ_3) and 45° (θ_4) respectively. Similar results were reported by Chhinnan et al., (1975). The corresponding reduction in SPI was 9.2, 13.3, 15.3 and 11.6 per cent with an increase in peripheral velocity up to 0.25 ms^{-1} (V_4) which was in close agreement with the results reported by Bakhtiari and Loghavi, (2009).

3.1.3. 25 per cent more than Maximum Seed Dimension (S_3)

Though the trend exhibited with cell geometry having 25 per cent more than maximum seed dimension (S_3) was similar to that of cell geometry (S_2), the effect was more predominant with 11.7, 9.4, 11.7 and 13.3 per cent increase in SPI at 30° (θ_1), 35° (θ_2), 40° (θ_3) and 45° (θ_4) inclination of seed metering disc respectively when the peripheral velocity of seed metering disc was increased from 0.15 (V_2) to 0.20 ms^{-1} (V_3). The corresponding reduction in SPI was 11.7, 6.2, 10.5 and 11.2 per cent with an increase in increase in peripheral velocity up to 0.25 ms^{-1} (V_4) which is in close agreement with the results reported by Sahoo and Srivastava, (2008). The highest SPI value of 86.85 per cent was registered for when the peripheral velocity was 0.20 ms^{-1} (V_3) and inclination of seed metering disc was 45° (θ_4).

3.2. Effect of Inclination of Seed Metering Disc (θ) on SPI

With the increase in inclination of seed metering disc from 30° (θ_1) to 45° (θ_4), there was marginal variation in SPI at selected levels of peripheral velocity (V) and cell geometry (S). In general the effect of inclination of the seed metering disc on SPI was not predominant as inferred from Figure 1 and 2.

3.3. Effect of Cell Geometry on SPI

The effect of cell geometry (S) on SPI at selected levels of peripheral velocity of the seed metering disc (V) and inclination of seed metering disc (θ) is shown in Figure 2.

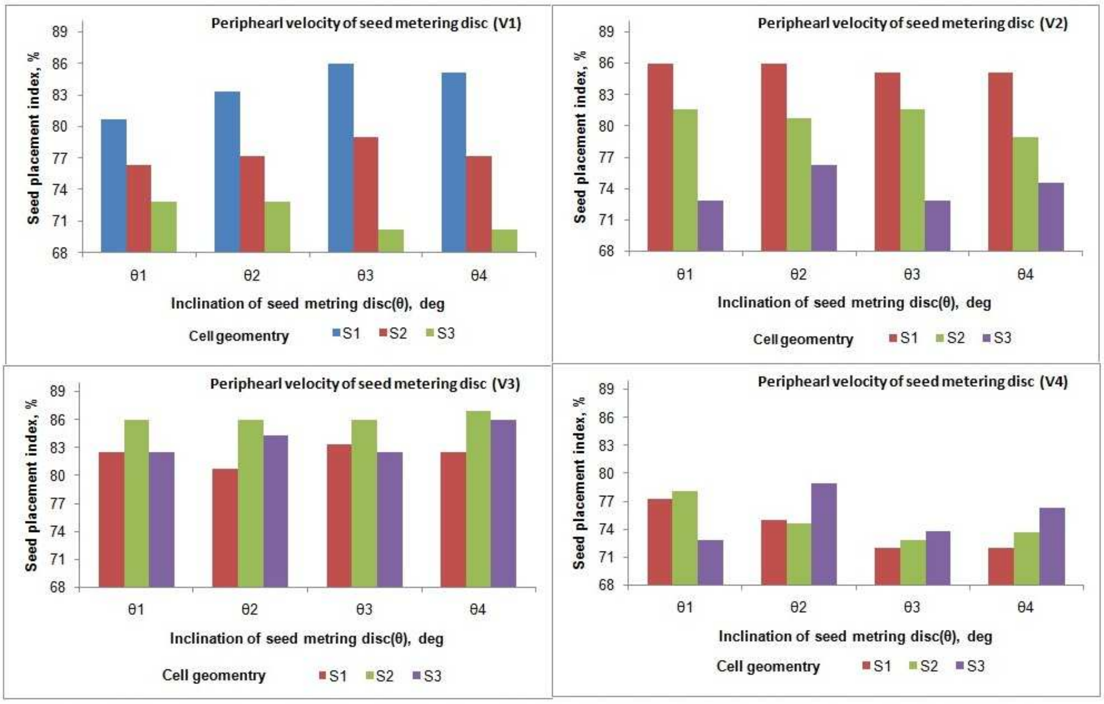


Figure 2: The Effect of Cell Geometry (S) on SPI at Selected Levels of Peripheral Velocity of Seed Metering Disc(V) and Inclination of Seed Metering Disc(θ)

3.3.1. 0.10 ms^{-1} Peripheral Velocity of Seed Metering Disc (V_1)

It is inferred that increase in cell geometry from 4.25 mm (S_1) to 5.31 mm (S_3) lowered the seed placement index by 14.6 per cent. This might be due to the fact that multiple seeds occupied the larger size of the cell (S_2 and S_3), leading to occurrence of higher number of hills with multiple seeds and hence reduced value of SPI. The highest SPI of 85.97 per cent was registered for cell geometry (S_1) and 40° (θ3) inclination of the seed metering disc.

3.3.2. 0.15 ms^{-1} Peripheral Velocity of Seed Metering Disc (V_2)

At peripheral velocity of 0.15 ms^{-1} (V_2), the same trend as observed with peripheral velocity of 0.10 ms^{-1} (V_1) was reflected with 13.3 per cent reduction of SPI.

3.3.3. 0.20 ms^{-1} Peripheral Velocity of Seed Metering Disc (V_3)

In general, it is noticed that the cell geometry (S_2) having 10 per cent more than the maximum seed dimension yielded higher values of SPI than cell geometry S_1 and S_3.. The occurrence of a number of hills with no seed in cell size 4.25 mm (S_1) was more since the maximum seed dimension and the cell size are the same without any allowance for accommodating extra seed. The cell size 5.31 mm (S_3) has 25 per cent of additional space to accommodate multiple seeds and hence the occurrence of a number of hills with multiple seeds was more than 4.25 mm (S_1) and 4.67 mm (S_2). Comparison of distribution of seed count per hill on the row with the selected three levels of cell geometry revealed that the number of hills with no seed and number of hills with multiple seeds in 4.67 mm cell size (S_2) was lesser than 4.25 mm (S_1) and 5.31 mm (S_3).

3.3.4. 0.25 ms^{-1} Peripheral Velocity of Seed Metering Disc (V_4)

At a higher peripheral velocity of the seed metering disc (V_4), the occurrence of a number of hills with no seed was more in all the selected levels of cell geometry (S) and hence the SPI was lower when compared with the peripheral velocity of seed metering disc V_1, V_2 and V_3. This might be due to relatively shorter time availability for the cell fill at higher peripheral velocity.

4. CONCLUSIONS

Based on the analysis of the results, the following conclusions are drawn.

- The effect of inclination of the seed metering disc on SPI was not predominant.
- At 0.10 ms^{-1} peripheral velocity of the seed metering disc, increase in cell geometry from 4.25 to5.31 mm lowered the seed placement index by 14.6 per cent.
- Increase in cell geometry from 4.25 to 5.31 mm lowered the seed placement index by 13.3 per cent at a peripheral velocity of 0.15 ms^{-1}.
- At 0.20 ms^{-1} peripheral velocity of the seed metering disc, the cell geometry 4.67 mm (10 per cent more than the maximum seed dimension) yielded higher SPI than the cell geometry of 4.25 mm and 5.31 mm.

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